BY HAROLD KINLEY

The value of ferrite RF isolators

Proper use at crowded communications sites can reduce intermodulation effects

The class C final stage of a transmitter can be a hot breeding ground for intermodulation products. These intermodulation products travel back up the transmission line to the antenna and can wreak havoc on nearby receivers. This is caused by high-level signals entering the final stage through the antenna and transmission line.

Attenuating these high-level signals before they reach the mixing point (class C final stage) can greatly reduce the level of the intermodulation product(s) formed there. By attenuating the mixing components before they reach the mixing point, a great advantage or leverage is obtained.

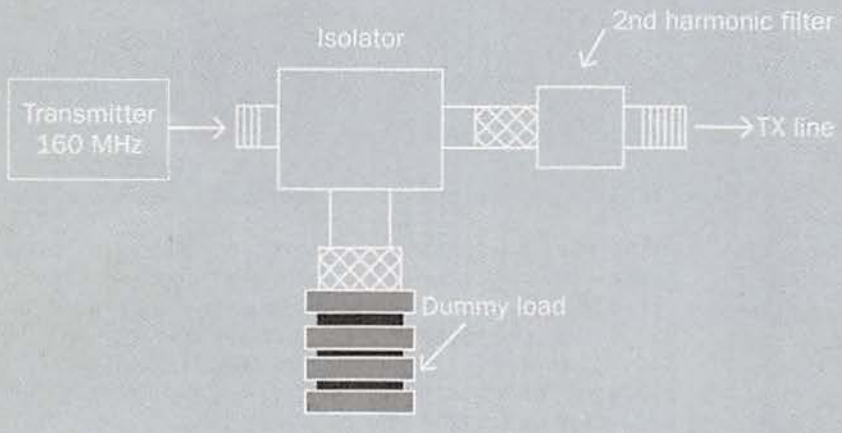
Using ferrite radio frequency (RF) isolators between the transmitter and the antenna is good practice. Many times it is possible to manipulate the tuned frequency of the isolator in order to achieve better results in suppressing intermodulation products that are formed within the final class C stage of the transmitter. Figure 1 shows a typical arrangement using a ferrite RF isolator placed between the transmitter and the transmission line. This particular isolator is a single-section isolator.

Referring to Figure 1, the output of the transmitter is connected to the input port (left side) of the isolator. The output port (right side) is connected, through a second harmonic filter, to the transmission line. The load port (bottom) is connected to the dummy load. Fairly strong second harmonics can be generated within the ferrite isolator. Therefore, the second harmonic filter is used to suppress this second harmonic. It usually is unnecessary to use the special second harmonic filter when bandpass filters are employed at the transmitter output.

In the forward direction, the isolator is very broadband and causes very little attenuation to the transmitter output signal. For example, a typical single-section isolator of the type shown in Figure 1 might offer as little as 0.25 dB of insertion loss in the forward direction. This means that 94% to 95% of the power applied to the input of the isolator appears at the output. For example, 100 W at the input to the isolator produces 94 W to 95 W at the output.

Figure 2 on page 41 represents a printout from a spectrum analyzer that shows the response of the isolator in the reverse direction. That is, the swept signal is applied to the output port, and the response is taken from the input port. As shown, the center frequency is set to 160 MHz, and the sweep span is 40 MHz, or ±20 MHz. This sets the range from 140 MHz to 180 MHz. The marker is set to approximately 156 MHz (one division to the left of center). The amplitude or vertical scale is set to 10 dB per division. The low point of the notch (at 160 MHz) is approximately 40 dB down, indicating an isolation of 40 dB at 160 MHz.

Figure 1



This is a typical setup using a ferrite RF isolator. Since ferrite isolators tend to generate rather strong second harmonics, a second harmonic filter is usually placed on the output of the isolator. See text for more details.

Now, suppose that there is a transmitter operating nearby at a frequency of 156 MHz (frequency A) and another transmitter nearby operating at 157 MHz (frequency B). Further suppose that there is a receiver nearby operating on a frequency of 155 MHz (frequency C). The mathematical relationship between these frequencies can be expressed by the following equation:

$2A - B = C$

Plugging the numbers

from our example into this equation yields the following result:

2 x 156 – 157 = 155 MHz

The reader will recognize this as a third-order intermod product. Let's assume that without the isolator in the line that this third-order intermod signal is at -20 dBm at the antenna. With the isolator in the line and with the response shown in Figure 2, the 156 MHz signal is attenuated by approximately 23 dB, and the 157 MHz signal would be attenuated by approximately 25 dB. The total attenuation to the intermod signal can be expressed by the following:

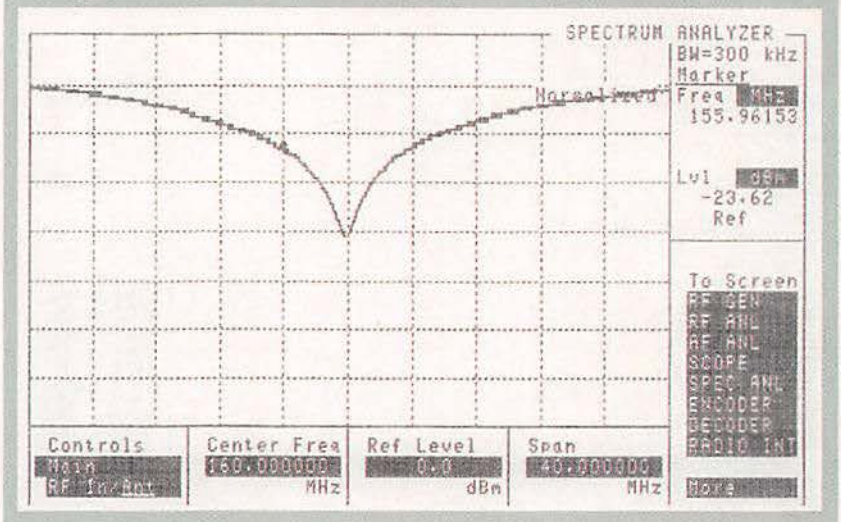
2 x 23 + 25 = 71 dB

Thus, the intermod signal at C is reduced to:

-20 – 71 = -91 dBm

It is vital to remember the leverage factor. The factor 2A found in the equation on page 40 represents leverage of 2 times the attenuation of signal A. And, since the coefficient of B is 1, we only get

Figure 2



This printout shows the response of the isolator in the reverse direction. The isolation at 160 MHz is greater than 40 dB. The isolation at 156 MHz is about 23 dB.

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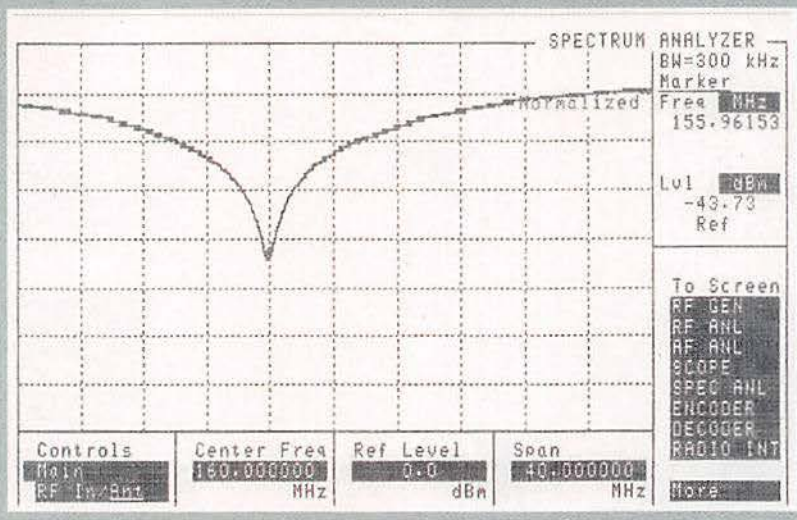
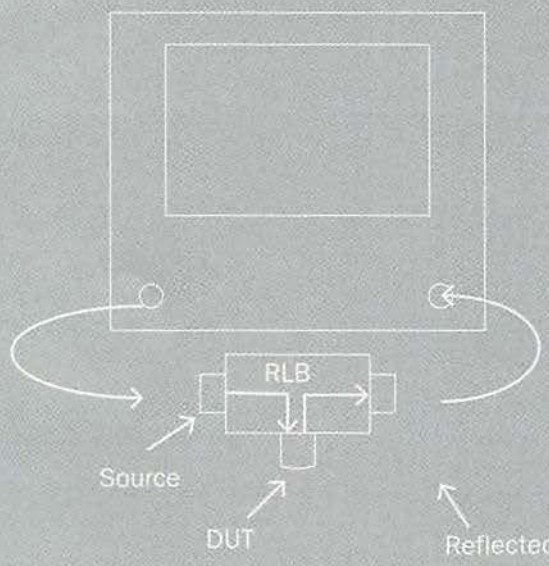
Figure 3



This printout shows the response of the isolator after being retuned to 156 MHz. Notice that the isolation at 156 MHz is now better than 43 dB. And, the isolation at 157 MHz is approximately 33 dB.

Figure 4



Before the return loss bridge is used, the normalization procedure should be performed. Using this test setup and a shorted connector connected to the DUT port, the response is normalized to 0 dB. This nulls out the losses of the cables and the losses in the bridge itself.

actual attenuation equal to signal B times 1. How can we use this leverage factor to achieve maximum attenuation of the intermod signal on frequency C? We retune the isolator to the frequency with the highest coefficient to get maximum leverage and thus maximum attenuation of the intermod signal.

Figure 3 shows the response of the isolator after it has been retuned for maximum isolation at 156 MHz. As seen from the response curve in Figure 3, the attenuation of signal A (156 MHz) is approximately 43 dB, and the attenuation of signal B (157 MHz) is approximately 33 dB. The total attenuation of the intermod signal at frequency C (155 MHz) is expressed by the following equation:

$2 \times 43 + 33 = 119$ dB

Thus, the intermod signal at C is reduced to a level of:

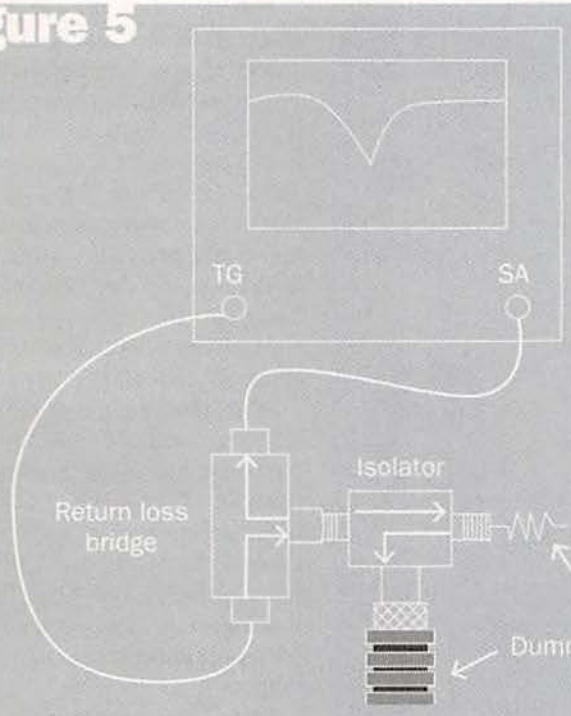
$-20 - 119 = -139$ dBm

At a level of -139 dBm, the intermod signal is unlikely to cause any harm.

Another important test is to determine the impedance match at the input and output ports of the isolator. A return loss bridge is used for this test. First, the return loss bridge and the interconnections must be normalized. The normalization procedure is performed using the test setup in Figure 4. The test setup for checking the impedance match at the input port of the isolator is shown in Figure 5 on page 43, while the return loss at the input port is shown in the printout in Figure 6 on page 44. The return loss at 160 MHz is more than 50 dB. This indicates a VSWR of approximately 1.006:1, indicating an excellent match.

The same procedure is used to check the impedance match at the output port. The connections to the input and output ports are simply reversed from that shown in Figure 5. The printout for this procedure is depicted in Figure 7 on page 44. The return loss at the output port is greater than 45 dB at 160 MHz. This represents a VSWR of approximately 1.01:1—again, an excellent match.

Figure 5



The setup shown here is used to check the impedance matching at the input port of the isolator. The tracking generator is connected to the source port of the return loss bridge while the spectrum analyzer is connected to the reflected port of the return loss bridge.

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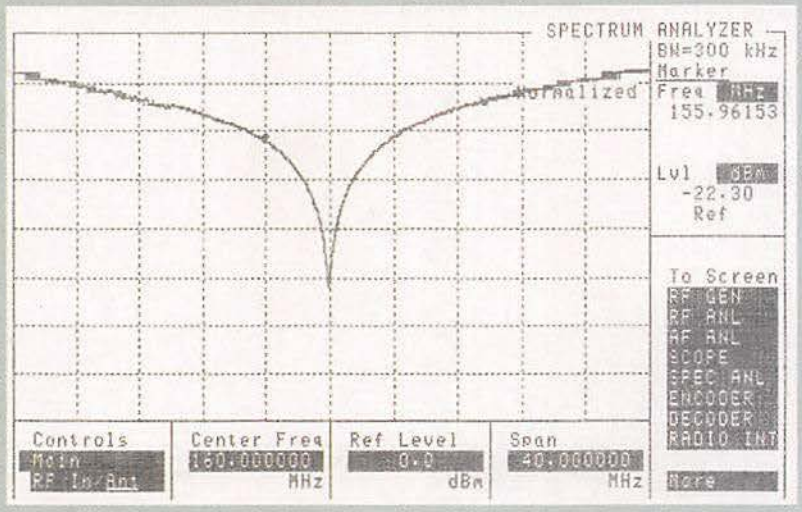
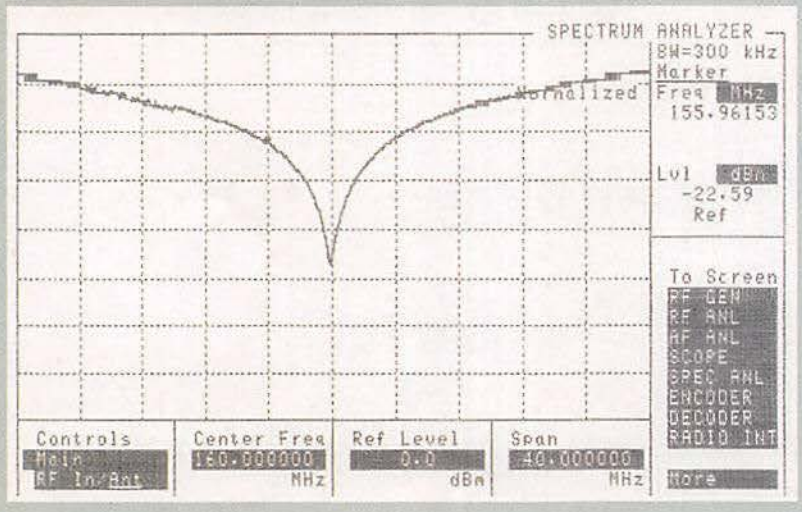
- Signal Enhancement Prod
- Amplifiers
- Antennas

Figure 6



This printout shows the return loss at the input port of the isolator. The return loss is better than 50 dB, indicating a VSWR of approximately 1.006:1—an excellent match.

Figure 7



The return loss at the output port of the isolator is performed in the same manner as described for the input port—the connections are simply reversed. This printout shows that the return loss at the output port is greater then 45 dB. This represents a VSWR of approximately 1.01:1—also an excellent match.

Now, let's look at a situation where the transmitter output is 100 W at 160 MHz, and the reflected power appearing at the output port of the isolator is 20 W. Referring to the printout in Figure 3 on page 42, the isolation at 160 MHz is about 22 dB. This means that the RF power coming into the isolator's output port (20 W) is attenuated by 22 dB as seen at the transmitter output. Thus, the reflected power appearing at the transmitter output is 20 W attenuated by 22 dB, or 0.13 W.

With a forward power of 100 W and reflected power of 0.13 W, the VSWR at the transmitter output is less than 1.1:1. If the forward power at the output port of the isolator is 95 W, and the reflected power is 20 W, then the VSWR at that point is around 2.7:1. Thus, the isolator is doing an excellent job of maintaining the proper impedance at the transmitter output.

Some important points to observe when using ferrite RF isolators are:

- Observe the manufacturer's recommendation concerning the physical mounting of the isolator.
- Make sure the isolator is properly tuned.
- Use proper 50 ohm load at the load port (usually supplied by the manufacturer).
- Check forward power at the input and output ports of the isolator.
- Calculate the insertion loss from the forward power measurements.
- Check insertion loss against the manufacturer's specifications.
- Never place an isolator in the receive leg.
- The dummy load at the load port should be able to handle at least 50% of the transmitter power.
- Make sure that the isolator is not over-heating (this can lead to destruction).
- Use a second harmonic filter when appropriate.

When properly used, isolators can significantly reduce interference problems at crowded communication sites.

Until next time—*stay tuned*! ■